

Final Technical Report

Twelfth International Symposium on Molten Salts

Program Grant Number F49620-99-1-0166

Gery R. Stafford
The Electrochemical Society, Inc.
10 South Main Street
Pennington NJ 08534-2896

September 2000

20001020 021

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REPORT DOCUMENTATION PAGE

AFRL-SR-BL-TR-00-

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estim: reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jeff. Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE 30 Sep 2000	3. REPORT TYPE Final Report, period 01 Jun 99 - 29 Feb 00
4. TITLE AND SUBTITLE Twelfth International Symposium on Molten Salts		5. FUNDING NUMBERS F49620-99-1-0166	
6. AUTHOR(S) Gery R. Stafford			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) The Electrochemical Society, Inc 10 South Main Street Pennington NJ 08534-2896		8. PERFORMING ORGANIZATION REPORT NUMBER N/A	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR/NL 801 North Randolph St. Arlington VA 22203-1977		10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED			12b. DISTRIBUTION CODE UNLIMITED
13. ABSTRACT (Maximum 200 Words) The Twelfth International Symposium on Molten Salts was held during the 1999 Joint International Meeting in Honolulu Hawaii, October 17-22, 1999. This meeting served as the 196 th Meeting of the Electrochemical Society and the 1999 Fall Meeting of the Electrochemical Society of Japan. The co-organizers of this symposium were Hugh C. De Long, United States Naval Academy; Paul C. Trulove, Air Force Office of Scientific Research; Gery R. Stafford, National Institute of Standards and Technology; and Shigehito Deki, Kobe University. Speakers came from over 15 different countries and well over two thirds of the papers presented were by authors from outside North America. The diversity of the topics covered by the papers presented at this symposium indicates the dynamic nature of molten salt research. This symposium continues to be a very popular venue for presentation of cutting edge research related to molten salts. Over 85 papers were presented on topics ranging from applications of room-temperature molten salts to theoretical investigations of molten salt structures.			
14. SUBJECT TERMS Molten Salts, Ionic Liquids, Spectroscopy, Electrochemistry, Electrodeposition			15. NUMBER OF PAGES 31
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT

NSN 7540-01-280-5500

DTIC QUALITY INSPECTED 4

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

MOLTEN SALTS XII

Twelfth International Symposium on Molten Salts

(Physical Electrochemistry Division/High Temperature
Materials Division/Electrodeposition Division)

This symposium will provide an international and interdisciplinary forum centered on innovative basic and applied research performed in molten salts and ionic liquids. Contributed papers are solicited in all areas of chemistry, electrochemistry, electrochemical engineering, and physics related to molten salt research. Topics of interest include: 1. Electrochemical Power, e.g., batteries, fuel cells, capacitors, and photovoltaics; 2. Homogeneous and Heterogeneous Reactions, e.g., catalysis, inorganic and organic syntheses, oligomerizations, and polymerizations; 3. Electrodeposition, e.g., metal electrowinning, the deposition of alloys, semiconductors, intermetallics and layered structures, the structural characterization of electrodeposits, metalliding and surface modification, and characterization of electroactive species; 4. Separations, e.g., selective extractions, immobilized molten salt gas membranes, and electrochemical gas separations; 5. Molten Salt Promoted Corrosion Phenomena; 6. Solute and Solvent Structural Investigations; and 7. New Innovative Molten Salts and Molten Salt Mixtures, e.g., hydrophobic molten salts and molten salt mixtures, liquid clathrates, low vapor pressure (vacuum resistant) molten salts, air-insensitive molten salts.

Keynote lectures will be presented by invited speakers. Depending upon the number of papers received, a poster session may be planned. Student participation is highly encouraged, and it is anticipated that some funds will be available for student support. Publication of a Proceedings Volume is planned. Authors are required to provide a camera-ready copy of their paper in the correct format and a list of keywords at or before the Meeting. All papers will be reviewed for content.

Abstracts, suggestions, and inquiries should be sent to the ECS Headquarters Office and one of the Symposium Organizers: H. C. De Long, AFOSR/NL, 801 North Randolph Street, Room 732, Arlington VA, 22203-1977, USA, Phone: (202) 767-7761, Fax: (202) 404-7475, E-mail: hugh.delong@afosr.af.mil; S. Deki, Department of Chemical Science and Engineering, Faculty of Engineering, Kobe University, Rokkodai, Nada, Kobe 657, Japan, Phone: 81(78) 803-1155, Fax: 81 (78) 803-1169, E-mail: deki@iclna.kobe-u.ac.jp; D. A. Shores, Corrosion Research Center, University of Minnesota, 151 Admundson Hall, 221 Church St SE, RM 112, Minneapolis, MN 55455 USA, Phone: (612) 625-0014, Fax: (612) 626-7246, E-mail: dshores@marron.tc.umn.edu; G. R. Stafford, National Institute of Standards and Technology, Metallurgy Division, Building 224 B166, Gaithersburg, MD 20899 USA, Phone: (301) 975-6412, Fax: (301) 926-7679, E-mail: stafford@tiber.nist.gov; or P. C. Trulove, Department of Chemistry, United States Naval Academy, Annapolis, MD 21402 USA, Phone: (410) 293-6610, Fax: (410) 293-2218, E-mail: trulove@brass.nadn.navy.mil.

This symposium will provide an international and interdisciplinary forum centered on innovative basic and applied research performed in molten salts and ionic liquids. Contributed papers are solicited in all areas of chemistry, electrochemistry, electrochemical engineering, and physics related to molten salt research. Topics of interest include: 1. Electrochemical Power, *e.g.*, batteries, fuel cells, capacitors, and photovoltaics; 2. Homogeneous and Reactions, *e.g.*, catalysis, inorganic and organic syntheses, oligomerizations, and polymerizations; 3. Electrodeposition, *e.g.*, metal electrowinning, the deposition of alloys, semiconductors, intermetallics and layered structures, the structural characterization of electrodeposits, metalliding and surface modification, and characterization of electroactive species; 4. Separations, *e.g.*, selective extractions, immobilized molten salt gas membranes, and electrochemical gas separations; 5. Molten Salt Promoted Corrosion Phenomena; 6. Solute and Solvent Structural Investigations; and 7. New Innovative Molten Salt Mixtures.

Keynote lectures will be presented by invited speakers. Depending upon the number of papers received, a poster session may be planned. Student participation is highly encouraged, and it is anticipated that some funds will be available for student support.

A proceedings volume will be published. Authors are required to provide a camera-ready copy of their papers in the correct format and a list of keywords at or before the Meeting. All papers will be reviewed for content.

Abstracts, suggestions, and inquiries should be sent to the ECS Headquarters Office and the Symposium Organizers:

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1999 Joint International Meeting - Honolulu, Hawaii

October 17-22, 1999

Twelfth International Symposium on Molten Salts

**Physical Electrochemistry Division/ Electrodeposition Division/ High
Temperature Materials Division**

Monday, October 18, 1999

Coral Ballroom I, Mid Pacific Conference Center

Room-Temperature Molten Salts

Co-Chairs: P.C. Trulove and H.C. DeLong

10:00 Opening Remarks

10:05 Buffered Chloroaluminate Melts and Latent Acidity - R. Osteryoung (North Carolina State University)

10:35 Heterogeneous Catalytic Hydrogenation with Supported Ionic Liquid Membranes - R. Carlin (Office of Naval Research), T. Cho (Worcester Academy), and J. Fuller (United States Air Force)

11:05 Ionic Liquid-Polymer Impregnated Nafion Electrolytes - J. Fuller (United States Air Force) and R. Carlin (Office of Naval Research)

11:25 Ionic Liquid, Graphite nad Gel Polymer Electrolytes and Electrodes Using 1,2-dimethyl-3-propyl-imidazolium tetrafluoroborate. - T. Sutto (Naval Research Laboratory), H. De Long (Air Force Office of Scientific Research), and P. Trulove (U.S. Naval Acadmey)

11:45 Polymer Extractions by Room Temperature Chloroaluminate Molten Salts - J. Wilkes, P. Castle, C. Humphrey, F. Layo, and R. Slanger (US Air Force Academy)

Room-Temperature Molten Salts (cont'd)

Co-Chairs: H.C. DeLong and P.C. Trulove

- 1:30 Synthesis of Precursors to III-V Materials via Ambient Temperature Chloroaluminate Molten Salts - M.T. Carter, M.E. Berton, and K.L. Kies (Eltron Research, Inc.)
- 1:50 The Redox Chemistry of Plutonium in Room Temperature Ionic Liquids - D. Costa and W. Smith (Los Alamos National Laboratory)
- 2:10 Electrochemical Behavior of Lanthanum Ion in LaCl_3 Saturated AlCl_3 -EMIC Room Temperature Molten Salts - T. Tsuda and Y. Ito (Kyoto University)
- 2:30 Electrochemical Behavior of Silver(I) in 1-ethyl-3-Methylimidazolium Tetrafluoroborate Prepared by a Novel Procedure - Y. Katayama, S. Dan, T. Miura, and T. Kishi (Keio University)
- 2:50 Electrochemical Reduction of Ta(V) in the TaCl_5 -EMIC Low Temperature Molten Salt - M. Morimitsu, T. Matsuo, and M. Matsunaga (Kyushu Institute of Technology)
- 3:10 Thirty-Minute Intermission
- 3:40 Electrochemical Behavior of Vanadium(II / III) and Niobium(IV / V) in Basic 1-ethyl-3-methylimidazolium Chloride - Aluminum Trichloride Molten Salt - Y. Katayama, I. Konishiike, K. Shinozaki, T. Miura, and T. Kishi (Keio University)
- 4:00 Hydride Ion Behavior in Acidic Chloroaluminates at Ambient Temperature - D. Wassell, K. Johnson, and L. Mihichuk (University of Regina)
- 4:20 Reactions of Alkanes and Cycloalkanes in Ambient Temperature Ionic Liquids - M. Elrutb, K. Johnson, Y. Patell, and R. Simank (University of Regina)
- 4:40 Application of Ionic Liquids as Electrolytes in Lithium Rechargeable Cells - J. Caja, T.D.J. Dunstan (Electrochemical Systems, Inc.), D.M. Ryan (Wright-Patterson AFB), and V. Katovic (Wright State University)
- 5:00 Transition Metal Centered Reactions in Ambient-Temperature Ionic Liquids - T. Welton, T. Welton, G.B. Young, and P. Dyson (Imperial College)

Tuesday, October 19, 1999

Room-Temperature Molten Salts (cont'd)

Co-Chairs: M.T. Carter and J.S. Wilkes

8:00 Opening Remarks

8:05 Studies of Cation Transport in Molten Salts and Molten Salt-Polymer Gels by Pulsed-Field-Gradient Spin-Echo NMR - P. Trulove (US Naval Academy), R. Mantz (AFRL/PRSF), H. De Long (Air Force Office of Scientific Research), and R. Osteryoung (North Carolina State University)

8:25 The Density and HNMR Spectra of Binary Solution of N-methylpyrdinium Iodine and N-Methylpyridinium Chloride - D.S. Newman, D.Y. Chen, and C. Silkowski (Bowling Green State University)

8:45 Improvement of Ionic Conductivity of Room Temperature Molten Salt Based on Quaternary Ammonium Cation and Imide Anion - H. Matsumoto, M. Yanagida, K. Tanimoto, T. Kojima, Y. Tamiya, and Y. Miyazaki (Osaka National Research Institute)

9:05 Low Temperature Molten Vilogens-Phase Transition and Electrochemical Properties- - K. Ito Akita and H. Ohno (Tokyo University of Agri. and Tech.)

9:25 Electrochemical Properties of Room Temperature Molten Salts with Tetrafluoroborate Anion - A. Noda and M. Watanabe (Yokohama National University)

9:45 Coffee Break in the Exhibit Hall

10:15 Structure and Bonding in Ionic Liquids - A. Carmichael, C. Hardacre, J. Holbrey, K. Seddon, and M. Nieuwenhuyzen (The QUILL Centre)

10:35 Structural Characteristics of Imidazolium Ionic Liquids: The non-Haloaluminates - A. McEwen (Covalent Associates, Inc.)

Structural Investigations of Molten Salts

Co-Chairs: J.S. Wilkes and M.T. Carter

10:55 Structural and Redox Properties of Vanadium Complexes in Molten Salts of Interest for the Catalytic Oxidation of Sulfur Dioxide - S. Boghosian, A. Chrisanthopoulos, and R. Fermann (Forth-ICE/HT)

11:20 Structural Analysis of Molten Rare Earth Halides by EXAFS - Y. Okamoto, H. Motohashi, M. Akabori, and T. Ogawa (Japan Atomic Energy Research Institute)

11:40 Influence of External Electromagnetic Fields on the Structure and Diffusion Properties of Molten Salts - P. Zilberman, A. Chernikov, V. Znamensky, and V. Rogov (Institute of Informatics and Problems of Regional Development)

Structural Investigations of Molten Salts (cont'd)

Co-Chairs: S. Deki and M.-L. Saboungi

1:30 Towards an Understanding of Ionic Transport in Lithium Conducting Polymers - M.-L. Saboungi, G. Mao (Argonne National Laboratory), H. Fischer (ILL), W.S. Howells (ISIS), and D.L. Price (Argonne National Laboratory)

1:50 Computational Studies of Lithium Polymer Electrolytes - L. Curtiss and A. Baboul (Argonne National Laboratory)

2:10 The Reverse Monte Carlo Studies of Molten Alkali Carbonates - S. Kohara (Japan Synchrotron Radiation Research Institute), K. Suzuya, and H. Ohno (Japan Atomic Energy Research Institute)

2:30 **CANCELLED** Molecular Dynamics Modelling of Microstructure and Counterion Transport in Ionic Polymers - J. Clarke, C. Wong, and M. Banaszak (UMIST)

2:50 Structure of the MF-AlF₃-Al₂O₃(M=Li, Na, K) Melts - T. Ostvold, O.T. Gustavsen, and V. Danek (Slovak Academy of Sciences)

3:10 Thirty-Minute Intermission

Thermodynamic Studies in Molten Salts

Co-Chairs: M.-L. Saboungi and S. Deki

3:40 Electrical Conductivity and Melting Behavior of Inorganic Powder/Alkali-metal Carbonate Coexisting Systems - S. Deki, G. Cha, Y. Harada, M. Mizuhata, and A. Kajinami (Kobe University)

4:10 Concept of Mismatch and Relaxation Explains DC and AC Conductivities of Fragile Glass Forming Ionic Melts - K. Funke, B. Heimann, M. Vering, and D. Wilmer (Institut fuer Physikalische Chemie)

4:30 Density and Electrical Conductivity of Molten MgCl₂-CaCl₂ Binary Melt - Y. Sato, Y. Kuroda, T. Nagatsu, M. Hoshi, J.-I. Kim, and T. Yamamura (Tohoku University)

4:50 Chemical and Electrochemical Studies in Molten Carbonates Containing Silica - S. Devyatkin, A. Pisanenko, and V. Shapoval (INOC)

Wednesday, October 20, 1999

Thermodynamic Studies in Molten Salts (cont'd)

Co-Chairs: M. Gaune-Escard and A.K. Adya

10:00 Opening Remarks

- 10:05 Phase Diagram and Surface Tension of the System LiF-KF-K₂NbF₇ - M. Chrenkova, D.K. Nguyen, V. Danek, and A. Silny (Slovak Academy of Sciences)
- 10:30 Electrochemical Thermodynamic Estimation of M-H System in LiCl-KCl-LiH Melts - T. Nishikiori, T. Nohira, and Y. Ito (Kyoto University)
- 10:50 Salt-Amide Supercooled Mixtures - G. Berchiesi (Universita Camerino)
- 11:10 Thermodynamic Properties of Solid and Liquid LnCl₃ and LnCl₃-MCl Systems (Ln=Lanthanide ;M= Alkali) - M. Gaune-Escard and L. Rycerz (Universite de Provence)
- 11:30 Structural and Thermodynamic Properties of Molten UCl₃ and UCl₃-MCl (M = Li, Na, K and Cs) Systems - A. Adya, H. Matsuura (University of Abertay Dundee), R. Takagi (Tokyo Institute of Technology), L. Rycerz (Technical University of Wroclaw), and M. Gaune-Escard (IUSTI)
- 11:50 Study of Bicomponent Molten Salts by the Contact Melting Method - P. Zilberman, A. Chernikov, V. Znamensky, E. Goncharenko, and Y. Skaev (Institute of Informatics and Problems of Regional Development)

High Temperature Molten Salts

Co-Chairs: Y. Ito and T.R. Griffiths

1:30 Thin Film Hot Corrosion Studies of Oxidised and Carburized Type 310 Stainless Steel - T. Griffiths (The University of Leeds) and N. Phillips (T.R Oil Services Ltd.)

1:55 Electrochemical Behavior of Hydride Ion and Deuteride Ion in Molten Fluoride Systems - H. Qiao, T. Nohira, and Y. Ito (Kyoto University)

2:15 Electrochemical Reactions of Si and Evolution of SiH₄ in Molten Alkali Halide Systems - T. Nohira and Y. Ito (Kyoto University)

2:35 Study of the Anode Process on Carbon Electrodes in the Pure Magnesium Chloride Melt with Dissolved Magnesium Oxide at 1023K - M. Mohamedi (Tohoku University), B. Borresen, G.-M. Haarberg, and R. Tunold (NTNU)

2:55 Thirty-Minute Intermission

3:25 The Solubility of NiO and NiAl₂O₄ in Cryolite Melts - O.-A. Lorentsen (Norwegian University of Science and Technology), E.W. Dewing (Retired), and J. Thonstad (Norwegian University of Science and Technology)

3:45 A Novel Sensitive Method for Determining Oxygen Solubility in Molten Carbonates and Carbonate-Containing Melts: Reaction of Oxidising Species Formed with Uranium Dioxide - V. Volkovich, T. Griffiths (University of Leeds), D. Fray (University of Cambridge), M. Fields, and R. Thied (British Nuclear Fuels Plc.)

4:05 Performance of Li-Alloy/Ag₂CrO₄ Couples in Molten CsBr-LiBr-KBr Eutectic - R. Guidotti and F. Reinhardt (Sandia National Laboratories)

4:25 Internal Cation Mobilities in the Ternary Molten System (Na,K, Cs)Cl - M. Matsumiya and R. Takagi (Japan Atomic Energy Research Institute)

4:45 The Solubility of FeO and FeAl₂O₄ in Cryolite Melts - T.E. Jentoftsen (Norwegian University of Science and Technology), E.W. Dewing (Consultant), G.M. Haarberg (SINTEF Materials Technology), and J. Thonstad (Norwegian University of Science and Technology)

Max Bredig Award Banquet

Co-Chairs: S. Deki and H.C. DeLong

7:00 **PHYSICAL ELECTROCHEMISTRY DIVISION MAX BREDIG AWARD**
ADDRESS-Selected Topics of Molten Salt Electrochemistry - Y. Ito (Kyoto University)

Thursday, October 21, 1999

Electrodeposition in Molten Salts

Co-Chairs: G.R. Stafford and C.L. Hussey

- 8:00 Opening Remarks
- 8:05 Electrodeposition of Silver-Aluminum Alloys from Room-Temperature Chloroaluminate Molten Salts - C.L. Hussey and Q. Zhu (University of Mississippi)
- 8:30 Electrodeposition of Cu-Zn Alloys from a Lewis Acidic Zinc Chloride-1-Ethyl-3-methylimidazolium Chloride Molten Salt - P.-Y. Chen, M.-C. Lin, and I.-W. Sun (National Cheng-Kung University)
- 8:50 Electrodeposition and Pitting Corrosion of Aluminum-Manganese Alloys from Room Temperature Chloroaluminate Molten Salts - H. De Long (Air Force Office of Scientific Research) and J. Mitchell (Naval Research Laboratory)
- 9:10 Electrodeposition of Niobium and Tantalum from a Room-Temperature Molten Salt - G.T. Cheek, P.C. Trulove (United States Naval Academy), and H.C. De Long (Air Force Office of Scientific Research)
- 9:30 Coffee Break in the Exhibit Hall
- 10:00 The Electrodeposition of Al-Cu Alloys from Room-Temperature Chloroaluminate Electrolytes - G. Stafford, V. Jovic (NIST), Q. Zhu, S. Jones, and C. Hussey (University of Mississippi)
- 10:20 Electrodeposition and Dissolution of Nb and Al in Molten Chloride Bath - N. Kawaguchi, N. Maeda, Y. Sato, and T. Yamamura (Tohoku University)
- 10:40 Electrochemical Behaviour of Dissolved Niobium, Molybdenum and Tantalum Species in Molten Chloroaluminates - G.M. Haarberg (SINTEF Materials Technology) and G. Stafford (National Institute of Standards and Technology)
- 11:00 Electrodeposition of Tungsten in a Basic $ZnCl_2-NaCl$ (40-60 mol%) Melt - A. Katagiri and H. Takenishi (Kyoto University)
- 11:20 Direct Electrowinning of Liquid Titanium Metal Using by Direct Current Electro Slag Remelting Apparatus - T. Takenaka, M. Ishikawa, and M. Kawakami (Tohohashi University)
- 11:40 The Electrodeposition of Titanium from the Low Temperature Molten Electrolytes - H.-Y. Hsu, D.-L. Chen, H.-W. Tsao, and C.-C. Yang (National Yunlin University of Science and Technology)

Electrodeposition in Molten Salts (cont'd)

Co-Chairs: E.G. Polyakov and G.M. Haarberg

- 1:30 A Voltammetric Study of Titanium Electrorefining in Chlorotitanate Melts - L. Ortiz and D. Sadoway (Massachusetts Institute of Technology)
- 1:50 Nucleation and Diffusion Controlled Growth of Lead, Zinc and Magnesium from LiCl-KCl Eutectic Melt - T. Store (Hydro Aluminium), G.M. Haarberg, and R. Tunold (Norwegian University of Science and Technology)
- 2:10 Lower Oxidation State Niobium Oxofluoride Compounds: Possibility of Existence in Melts and Part in Electrochemical Processes - V.V. Grinevitch, A.V. Arakcheeva, V.A. Reznichenko (Russian Academy of Sciences), S.A. Kuznetsov (Russian Academy of Science), A.F. Vik, and T. Ostvold (University of Trondheim)
- 2:30 Titanium, Boron, and Titanium Diboride Deposition in Alkali Fluorochloride Melts - M. Chemla, F. Lantelme, A. Barhoun (UPMC), and J. von Barner (DTU)

Coral Lounge, Mid Pacific Conference Center

Poster Session (2:50 PM - 5:30 PM)

Co-Chairs: G.R. Stafford and P.C. Trulove

2:50 Authors may begin setting up their posters at 2:00 P.M.

- o **CANCELLED** Local Structures in Molten Aluminium - Alkali Fluorides - Z. Akdeniz, Z. Cicek, A. Karaman (University of Istanbul), and M.P. Tosi (Scuola Normale Superiore)
- o Electrodeposition of Metals from Molten Salts - A.M. Martinez Cuellar, G.M. Haarberg (Norwegian University of Science and Technology), Y. Castrillejo (Universidad de Valladolid), B. Borresen, and R. Tunold (Norwegian University of Science and Technology)
- o Electrochemical Epitaxial Growth of Diamonds in Ionic Melts - A. Gab, I. Novoselova, and V. Shapoval (Ukrainian Academy of Science)
- o Electrodeposition of Lanthanum and La-Ni Alloys by Molten Salts Electrolysis - C. Dias and E.J. Pessine (Institute of Energy and Nuclear Research - IPEN)
- o **CANCELLED** Solubility of Alumina in Hydroxide-Salts Melts - O. Zarubitskii and I. Skryptun (V.I. Vernadskii Institute of General and Inorganic Chemistry)
- o Temperature Dependence of Thermal Conductivity in Molten Alkali Metal Halides by MD Simulation - K. Takase, I. Akiyama, and N. Ohtori (Niigata University)
- o Electrical Conductivity and Nuclear Magnetic Resonance of Molten Lithium Borates - T. Katsumata, N. Suzuki, M. Shibasaki, and T. Matsuo (Toyo University)
- o Niobium Fluorocomplexes and Oxyfluorocomplexes in Fluoride Melts - V. Van, A. Silny, and V. Danek (Slovak Academy of Sciences)
- o The Variation of Structure with Composition for Mixed Molten Hydrate - A. Kajinami, S. Deki, M. Mizuhata, and M. Kubota (Kobe University)
- o Large Scale Molecular Dynamics Simulations for Molten Salts - Y. Okamoto, S. Ishizuki, and T. Ogawa (Japan Atomic Energy Research Institute)
- o Raman Spectra of K₂O-B₂O₃ Glasses and Melts - R. Akagi (Kobe University), N. Ohtori (Niigata University), and N. Umesaki (AIST)
- o Electrochemical Studies of Metal Dichalcogenide-Polymer Composite Electrodes in 1,2-dimethyl-3-propyl-imidazolium tetrafluoroborate and 1-ethyl-3-methyl-imidazolium tetrafluoroborate - T. Sutto (Naval Research Laboratory), H. De Long (Air Force Office of Scientific Research), and P. Trulove (U. S. Naval Academy)
- o Electrochemical Intercalation Studies of 1,2-dimethyl-3-propyl-imidazolium tetrafluoroborate and 1-ethyl-3-methyl-imidazolium tetrafluoroborate in Graphite and

Graphite-Polymer Composite Electrodes - T. Sutto, C. Sienerth (Naval Research Laboratory), H. De Long (Air Force Office of Scientific Research), and P. Trulove (U. S. Naval Academy)

- o Alumina Sensors in Hall-Heroult Electrolyte. - S. Rolseth, H. Gudbrandsen, and G.M. Haarberg (SINTEF Materials Technology)
- o The Catalytic Effect of a PT Electrode Surface on the Electrodeposition of Boron in Molten Flinak - G. Ett and E. Jorge Pessine (Institute of Energy and Nuclear Research - IPEN)

Friday, October 22, 1999

Coral Ballroom I, Mid Pacific Conference Center

Electrodeposition in Molten Salts (cont'd)

Co-Chairs: Y. Ito and S. Rolseth

- 8:00 Opening Remarks
- 8:05 Electrode Reactions of Borides of Refractory Metals in Fluoroborate Melt - M. Kawakami, T. Takenaka, and K. Nagao (Toyohashi University)
- 8:25 The Catalytic Effect of a Platinum of a Platinum Working Electrode on the Electrodeposition Potential of Boron - G. Ett and E.J. Pessine (Institute of Energy and Nuclear Research - IPEN)
- 8:45 The Effect of the Melt Composition on Electrode Processes and Structure of Tantalum-Boride Coatings - O. Makarova, L. Polyakova, E. Polyakov, A. Shevyryov (RAS), and N. Bjerrum (Technical University of Denmark)
- 9:05 Formation of Nitride Thin Films by Electrochemical Implantation - T. Goto and Y. Ito (Kyoto University)
- 9:25 Potential Response During the Alloying Process after Molten Salts Electrolysis - H. Yamamoto, K. Kuroda, R. Ichino, and M. Okido (Nagoya University)
- 9:45 The Electrode Processes of Y (III) on Copper Nickel Aluminum Electrodes and Surface Metalliding in Molten Salts - S. Duan (University of Science and Technology Beijing) and G. Jin (Tsinghua University)
- 10:05 Coffee Break in the Exhibit hall

Technological Applications of Molten Salts

Co-Chairs: R.A. Mantz and G.T. Cheek

- 10:35 Molten Salt Membrane Process for Chlorine Recovery - J. Johnson and J. Winnick (Georgia Institute of Technology)
- 11:00 Electrolytic Recovery of Molten Pulping Chemicals: An Alternative to the Kraft Causticizing Process - R. Wartena, J. Winnick (Georgia Institute of Technology), and P. Pfromm (Institute of Paper Science and Technology)
- 11:20 Electrochemical Flue Gas Cleaning using Molten Pyrosulfate-Based Membranes - S.B. Rasmussen, M. Eriksen, R. Fehrmann (Technical University of Denmark), and J. Winnick (Georgia Institute of Technology)
- 11:40 Electrochemical Promotion of Sulfur Dioxide Catalytic Oxidation - I. Petrushina (Technical University of Denmark), V. Bandur (V.I Vernaskii Institute of General and Inorganic Chemistry, National Academy of Sciences of Ukraine), F. Cappeln, and N. Bjerrum (Technical University of Denmark)

Technological Applications of Molten Salts (cont'd)

Co-Chairs: G.T. Cheek and R.A. Mantz

- 1:30 Determination of Gas Permeability of Molten Salts and Slag Adequate Medium - T. El Gammal and W.-H. Chung (Institute for Ferrous Metallurgy (IEHK))
- 1:50 Characterization of the LiSi/CsBr-LiBr-KBr/FeS₂ System for Potential Use as a Geothermal Borehole Power Source - R. Guidotti and F. Reinhardt (Sandia National Laboratories)
- 2:10 Development of a High Power Zebra Battery - J. Prakash (Illinois Institute of Technology)
- 2:30 Cell Efficiency in Bipolar Electrode Cell for Aluminum Electrorefining - M. Ueda, T. Ohmura, S. Konda, T. Sasaki, and T. Ohtsuka (Hokkaido University)
- 2:50 Electrolytic Production of Nitrogen Trifluoride with a Nickel Based Composite Electrode Prepared by HIP - A. Tasaka, T. Makino, Y. Suzuki, T. Maeda, K. Takao, T. Ueno, H. Takemura, and O. Yamaguchi (Doshisha University)
- 3:10 High Temperature Electrochemical Heat Pump Using Water Gas Shift Reaction-Electrolytic Reduction of Carbon Dioxide in Molten Carbonate - A. Ishihara, T. Fujimori, N. Motohira, K.-I. Ota, and N. Kamiya (Yokohama National University)

PREFACE

The Twelfth International Symposium on Molten Salts was held during the 1999 Joint International Meeting in Honolulu Hawaii, October 17-22, 1999. This meeting served as the 196th Meeting of the Electrochemical Society and the 1999 Fall Meeting of the Electrochemical Society of Japan. The Molten Salt Symposium was a resounding success due in no small part to the generous financial support of the Physical Electrochemistry, High Temperature Materials, and Electrodeposition Divisions of the Society. In addition, the Air Force Office of Scientific Research and the European Office of Aerospace Research and Development provided much needed funds to support the travel and registration of speakers for this symposium. The co-organizers of this symposium were Hugh C. De Long, United States Naval Academy; Paul C. Trulove, Air Force Office of Scientific Research; Gery R. Stafford, National Institute of Standards and Technology; and Shigehito Deki, Kobe University.

As in past years, this version of the molten salt symposium was truly an international affair. Speakers came from over 15 different countries and well over two thirds of the papers presented were by authors from outside North America. The diversity of the topics covered by the papers presented at this symposium indicates the dynamic nature of molten salt research. This symposium continues to be a very popular venue for presentation of cutting edge research related to molten salts. Over 85 papers were presented on topics ranging from applications of room-temperature molten salts to theoretical investigations of molten salt structures. The large number of papers presented at this symposium indicates the continued healthy state of molten salt research. The 1999 recipient of the Max Bredig Award was Professor Yasuhiko Ito of Kyoto University. In his award address, Professor Ito gave the audience a wry look back at his many years of molten salt research and the numerous colleagues who helped him along the way.

The editors wish to thank Prof. Trevor Griffiths, Prof. Graham Cheek, Prof. David Newman, and Dr. Robert Mantz for their much needed assistance in the review of articles for this proceedings. Furthermore, we wish to give a special thanks to Dr. Thomas Sutto for his many contributions to the organization and review of the proceedings. Finally, we would like to thank the U.S. Naval Academy, Department of Chemistry for their assistance with the numerous mailings required to get this symposium up and running.

Paul C. Trulove
AFOSR
January 2000



Dr. Yasuhiko Ito

Recipient of the 1999 Max Bredig Award

Dr. Yasuhiko Ito is Professor and Dean of the Graduate School of Energy Science at Kyoto University, Japan. He received his Bachelors of Science in 1963, his Masters of Science in 1965, and his Doctorate in 1969, all from Kyoto University. While still involved in his graduate work, Dr. Ito joined the staff of the Department of Industrial Chemistry at Kyoto University in 1968 as a research associate. After completing his graduate work, Dr. Ito left Kyoto University in September of 1969 to carry out a year long post-doctoral fellowship under the direction of Prof. Ibl at ETH in Zurich. Upon completion of his post-doctoral fellowship, Dr. Ito returned to his position at Kyoto University. He was subsequently promoted in 1971 to associate professor in the College of Liberal Arts and Sciences. In 1981, Dr. Ito moved to the Department of Nuclear Engineering at Kyoto University where, in 1989, he achieved the rank of professor. In 1996, Dr. Ito moved to the Graduate School of Energy Science at Kyoto University where he is currently the Dean.

Dr. Ito has published extensively in the area of molten salts. His often-cited research spans the entire range of molten salt chemistry. This includes molten salt electrochemistry, transport phenomena, chemical production processes, energy conversion processes, materials tailoring, and many others. Dr. Ito's current area of research focuses on processes and materials relating to converting solar, atomic, and chemical energies. His group is currently working on molten salts as a new energy medium, the inorganic synthesis of various nonaqueous systems, and electrochemical implantation for the preparation of functional materials.

Dr. Ito is an active member of The Electrochemical Society and has organized several international symposia, workshops, and conferences. Currently, Dr. Ito is chairman of the Molten Salts Committee of the Electrochemical Society of Japan. He is serving as an editor for the molten salt journal *Plasma and Ions*, and he is on the editorial boards for both *Electrochimica Acta* and *The Journal of Power Sources*.

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Al-Mn	517	Crystal structure	209
Al-Y	669	Cu-Al	535
Alumina	368,428,485	Cu-Y	669
Aluminum alloys	100	Cycloalkanes	143
Aluminum electrolysis	485		
Aluminum hydride	132	Density	313
Aluminum nitride	74	Dichalcogenide	43
Aluminum oxide	368	Diffusion	169,202
Arenes	12	DIME	32,43,54
Basic melt	122	Dimethyl aniline	12
Batteries	713	Dimethyl anthracene	12
Beti	222	DMPI	20,32,43,54
Bipolar electrode	723	DSC	193,222
Borides	624		
Boron	612	Electrical conductivity	383
Brønsted acidity	12	Electric field	356,363
Buffered molten salts	12	Electrochemical heat pump	744
		Electrochemical implantation	651
CaCl ₂	263	Electrodeposition	494,527,535,549
Carbonate melts	441		564,585,624,645
Carbon dioxide	744	Electronic absorption spectra	228
Catalysis	20,143	Electrorefining	723
Cation mobility	461	Electrowinning	428,578
Cell efficiency	723	Energy conversion	744
Ceramic	7,74	EXAFS	240,263
Chlorine	675		
Chloroaluminate melts	12	FeAl ₂ O ₄	473
Cobalt nitride	651	FeO	473
Composite electrode	32,43,54,732	Flue gas cleaning	694
Concept of mismatch		Fluoride melts	399,597,645
and relaxation	301	Free energy	535
Conductivity	117,186,193,222	Fuel cells	27,292
	292,301,376	Gel electrolyte	32,169

Geothermal borehole	451,701	Molar volume	177,461
Glasses	281,301	Molecular dynamics	275,341,356
Green Chemistry	65		363,376
		Molten carbonate	292,441,744
Heterogeneous catalysis	20	Molybdenum	559
Hexafluorophosphate	20	MOPAC	186
Hot film corrosion	392		
Hydrate melt	263	NaAl ₂ O ₄	428
Hydrides	132,324,399,407	Nafion	27
Hydrofluoride melt	110	NaCl-AlCl ₃	549
Hydrogenation	20,161	NaCl-KCl-CsCl	275,461
		Neutral buffered melts	12
Imide	186,193,222	Neutron diffraction	240,247,253
Interionic potential	356	Ni-NiCl ₂	713
IR spectroscopy	132	NiO	428
		Niobium	122,527,549,559,597
Lanthanide chloride	383	Nitride	74,651
Lanthanum	100,240,660	Nitride films	5
Latent acidity	12	Nitrogen trifluoride	732
Lewis acidity	12	NMR	169,177,202,383
LiAl	451	Nucleation	100,517,624
LiCl	263		
LiCl-KCl	324,549,651	Oxohalide melts	597,624,645
LiF	399,407	Oxygen solubility	441
LiF/KF/NaF	636	Oxy-sulfate complexes	228
LiH	324,399,407		
Li-KCl-CsCl	675	PEM	27
Li ₃ N	651	Phase composition	363
Li plating	186	Pitting corrosion	517
Li-Si	451,701	Plutonium	80
Li stripping	186	Polymer extractions	65
Lithium ion	150	Porous electrodes	713
Lithium polymer electrolytes	247	Potassium borate	281
		PVdf-HFP	32,43,54
Magnesium	624	Pyrite	701
Magnesium oxide	292,417	Pyrosulfate membrane	694
Manganese alloys	517,660		
MCFC	292	Raman spectroscopy	228,281
Membrane	675	Rechargeable cell	150
Methide	222	Recoil mass spectroscopy	209
Methyl pyridinium	177	Reverse monte carlo	253
MgCl ₂ -CaCl ₂	313	Rubidium complexes	333
MgCl ₂	417	Ruthenium catalyst	161
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SEM/EDX	392,517,585,660	V ₂ O ₅	694
SiH ₄	407		
Silane	407	Water gas shift reaction	744
Silicon	407		
SILM	20	XAFS	209
Silver	110,494	X-ray crystallography	209
Silver aluminum alloys	494	X-ray diffraction	240,253,341,505
Slag	578		517,585,645,660
Sodium carbonate	685		
Sodium/nickel chloride	713	Yttrium	669
Sodium hydroxide recovery	685	Yttrium chloride	341
Solubility product	12		
Solvent-solute interaction	204	ZnB ₂	635
Square wave voltammetry	417	ZEBRA battery	713
Stainless steel	392	Zinc chloride	263,505
Surface metallidning	669	ZnCl ₂ -NaCl	568
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Tantalum	117,527,559,624		
Tantalum boride	645		
Tantalum melt	117		
Tetrafluoroborate	20,32,43,54,110		
	150,161,169,203		
Thermal analysis	222		
Thermal activation energy	383		
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	341,428		
TiB ₂	636		
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Titanium	578,585,612		
Tires	65		
Trifluoromethanesulfonate	27		
Tungsten	568		
UPD	535		
UCl ₃	275,341		
Uranium	80		
Uranium dioxide	441		
Vanadium	122		
Vanadium complexes	228		
Verlet algorithm	356		
Viologen	193		
Viscosity	202		